VERIFICATION

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[DOCUMENT NAME] SPECIFICATION

[TITLE OF THE INVENTION] SURFACE EMITTING SEMICONDUCTOR LASER AND COMMUNICATION SYSTEM USING THE SAME

[CLAIMS]

1. A surface emitting semiconductor laser comprising:

a laminate of semiconductor layers emitting multimode laser light; and

a block member blocking light of a specific mode among the multimode laser light emitted from the laminate.

2. The surface emitting semiconductor laser as claimed in claim 1, wherein:

the laminate comprises a substrate, a lower reflection mirror on the substrate, an upper reflection mirror, an active region, and a current confinement layer, the active region and the current confinement layer being interposed between the upper and lower reflection mirrors; and

the block member is provided in an emission aperture provided above the upper reflection mirror.

3. The surface emitting semiconductor laser as claimed in claim 1 or claim 2, wherein:

a top of the laminate is partially covered with an electrode so that an emission aperture can be defined; and

the block member is provided on the top of the laminate and is located in the center of the emission aperture.

4. The surface emitting semiconductor laser as claimed in claim 3, wherein:

a mesa is formed so as to extend at least from the upper reflection mirror and reach the current confinement layer, and the emission aperture and the block member has a shape related to an outer shape of the mesa.

5. The surface emitting semiconductor laser as claimed in claim 1 to claim 4, wherein a size of the block member is smaller than that of the current confinement layer.

6. The surface emitting semiconductor laser as claimed in claim 3 or claim 4, wherein the block member and the electrode are simultaneously formed.

7. The surface emitting semiconductor laser as claimed in claim 1 or claim 5, wherein the block member blocks light of a fundamental mode among the multimode laser light.

8. A surface emitting semiconductor laser comprising:

a surface emitting semiconductor laser capable of emitting multimode laser

beam;

a package that houses the surface emitting semiconductor laser and has a transmission window via which the multimode laser light is emitted; and

a block member that is provided in the transmission window and blocks light of a specific mode among the multimode laser light.

9. The surface emitting semiconductor laser as claimed in claim 8, wherein a diameter D1 of the block member is defined by the following formula:

[formula 1]

$$D1 = L1 \times 2\tan(\theta n/2)$$

where L1 is a distance from the surface emitting semiconductor laser device to the block member, θn is a divergence angle of emitted light of the specific mode from an optical source of the surface emitting semiconductor laser device in a far-field image of the multimode laser light.

10. The surface emitting semiconductor laser as claimed in claim 8 or claim 9, wherein the block member is equipped with an antireflection film that prevents the multimode laser light from being reflected by the block member.

11. The surface emitting semiconductor laser as claimed in claim 8, wherein the block member includes an absorption member that absorbs the light of the specific mode.

12. The surface emitting semiconductor laser as claimed in claim 8 or claim 11, wherein:

the surface emitting semiconductor laser device has a mesa that emits the multiple laser light; and

the block member has a circular shape.

13. The surface emitting semiconductor laser as claimed in claim 8 or 12, wherein:

the block member blocks of light of a fundamental mode among the multimode laser light; and

the divergence angle θn is a divergence angle of a diameter of the light of the fundamental mode from an optical source of the surface emitting semiconductor laser device.

14. An optical communication system using a surface emitting semiconductor laser as claimed in any of claims 1 to 11 as a light source, and comprising a multimode type optical fiber optically coupled with the light source.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[TECHNICAL FIELD]

The present invention relates to a surface emitting semiconductor laser of selective oxidization type, and more particularly, to a structure for controlling the optical power of a multimode surface emitting semiconductor laser.

[0002]

[BACKGROUND ART]

Recently, there has been an increased demand for a surface emitting semiconductor laser that can easily realize an arrangement of a two-dimensional array of sources in the technical fields of optical communications and optical recording. Such a surface emitting semiconductor laser is also called a vertical-cavity surface-emitting laser (VCSEL). The VCSEL has many advantages of a low threshold voltage, low power consumption, easy making of a circular spot of light and good productivity resulting from wafer-based evaluation.

[0003]

Nowadays, low-cost multimode optical fibers, which are typically plastic optical fibers (POF), are developed, and short-distance optical communications as short as a few meters to several hundreds of meters are getting the attention. Generally, long-distance optical communications employ the combination of a single-mode type optical fiber and an edge emitting semiconductor laser having a relatively long wavelength of 1.31 μm or 1.55 μm. However, these components are expensive and are unsuitable for applications in local areas that should be less expensive.

[0004]

An optical source used for the multimode optical fiber is required to be less expensive and avoid the use of a special optical system or driving system. The surface emitting semiconductor laser may satisfy the above-mentioned requirements and is one of the powerful options as the optical source for the multimode optical fiber. In order to use the surface emitting semiconductor laser as the optical source in optical communications utilizing the multimode optical fiber, it is desired to stabilize the oscillation mode and reduce jitter components contained in the optical output.

[0005]

Patent Documents 1 discloses a selective oxidization type surface emitting semiconductor laser in which an optically transparent layer is formed in a beam emitting aperture for controlling the oscillation transverse mode. The transparent layer may, for example, be a dielectric film, and functions to reduce the reflectance of an area that does not desire laser oscillation, so that the oscillation transverse mode can be controlled.

[0006]

Patent Documents 2 proposes a VCSEL intended to reduce the jitter (fluctuation in the turn-on delay time) of the laser device. A diffusion reinforcement region provided in the vicinity of the active layer is doped with an acceptor impurity of a high concentration, so that the number of holes induced in the quantum well region is approximately one-digit larger than the number of electrons therein. This increases the diffusion rate in the quantum well region.

[0007]

[PATENT DOCUMENT 1] Japanese Patent Application Publication No. 2001-156395

[PATENT DOCUMENT 2] Japanese Patent Application Publication No. 9-326530

[0008]

[PROBLEMS TO BE SOLVED BY THE INVENTION]

However, the conventional selective oxidization type semiconductor lasers have the following problems to be solved. Fig. 7 shows a beam profile and an optical output profile in a far-field image obtained when the multimode surface emitting semiconductor laser is used as an optical source. A symbol L denotes the distance from the optical source to the far-field image, and θ denotes the divergence angle of the diameter of the beam in the far-field image viewed from the center of the optical source. Generally, this kind of surface emitting semiconductor laser has a profile like a doughnut shape. More particularly, the laser beam of the fundamental mode exists within a spread or divergence angle θ_0 from the center of the optical source, and the beam profile is indicated by P0. When the divergence angle is greater than θ_0, the resultant laser beam is of a high-order mode in which the first-order mode or a higher-order mode in addition to the first-order mode is combined with the fundamental mode. The beam profile of the high-order-mode laser beam is indicated by P1. The optical output in the high-order mode indicated by P1 is grater than that of the fundamental mode. In other words, the outer portion P1 of the doughnut-like profile involved in the first-order or higher-mode is brighter than the inner portion P0 involved in the fundamental mode. The laser emissions in the oscillation modes do not have the same profiles and do not occur concurrently. Thus, there is a difference in response between the fundamental-mode light and the first-order or higher-order light. The difference in response causes the jitter in the optical signal when the multimode surface-emitting laser is used as the optical source.

[0009]

Fig. 8A shows an eye pattern that serves as an index for checking the quality

of the laser beam. The eye pattern is a pattern in which, when the laser beam is modulated (turned on and off), the modulated light signal is superimposed at random. The horizontal axis of the eye pattern denotes the time, and the vertical axis denotes the optical power. The eye pattern shown in Fig. 8A is an example observed when a multimode VCSEL capable of outputting light that has an optical power of 3 mW and a wavelength of 850 nm is used as the optical source. It can be seen from the eye pattern of Fig. 8A that each emission in the respective oscillation mode does not occur concurrently, so that a jitter J takes place. The jitter J is the time difference in response between the optical signals in the oscillation modes. The eye pattern ideally converges on a single line. If the optical output contains a jitter that exceeds a threshold time, the rate of incidence of error contained in the optical signal on the receive device side will considerably increase. This restrains the maximum bit rate achievable in the data link.

[0010]

The aforementioned transparent layer arranged in the vicinity of the beam emission aperture proposed in Patent Documents 1 is not intended to reduce the jitter in the multimode laser beam but to control the oscillation transverse mode. The VCSEL proposed in Patent Documents 2 does not have any mechanism for reducing the jitter.

[0011]

An object of the present invention is to provide a surface emitting type semiconductor laser of multimode type coupled with a multimode type optical fiber and capable of realizing high-speed optical communications and to provide an optical communication system using the same.

[0012]

[MEANS FOR SOLVING THE PROBLEMS]

A surface emitting semiconductor laser of the present invention is characterized in that a block member blocking a specific mode among multiple modes is arranged in an emission aperture through which laser is emitted. In the multimode, the times it takes to cause laser emission are slightly different from each other in the different modes, and the time differences result in differences in response performance. The presence of the block member in a propagation path of laser allows a laser beam of a specific mode to be blocked, so that the jitter of the light signal can be reduced. Preferably, among the oscillation modes, a mode having a relatively low frequency response is removed.

[0013]

Preferably, the surface emitting semiconductor laser comprises, on a substrate,

a lower reflection mirror, an upper reflection mirror, an active region, and a current confinement layer, the active region and the current confinement layer being interposed between the upper and lower reflection mirrors, and the block member is provided in an emission aperture provided above the upper reflection mirror. The upper reflection mirror may include multiple semiconductor layers of a first conduction type, and an electrode pattern for defining the emission aperture is formed on the multiple semiconductor layers, wherein the block layer is disposed in the almost center of the emission aperture. A mesa may be formed so as to extend at least from the upper reflection mirror and reach the current confinement layer, and the block member has a shape related to an outer shape of the mesa. For example, when the mesa has a column shape, the emission aperture and the block member may have circular shapes. The size of the block member may be selected in accordance with the specific mode to be blocked. The block member may be formed at the same time as the electrode pattern, and may be formed simply and easily.

[0014]

In the multimode surface emitting semiconductor laser of selective oxidization type, it is preferable to block the laser beam of fundamental mode among the multiple laser modes. This type of surface emitting semiconductor layer has a low frequency response in an inner region of a doughnut-shaped profile. The block member is arranged in the doughnut inner region to thereby block the fundamental mode layer light.

[0015]

The surface emitting semiconductor laser of the present invention is characterized by having a package that houses a surface emitting semiconductor laser capable of emitting multimode layer light and having a transmission window via which the multimode laser light is emitted, the transparent window having a block member that is provided therein and blocks light of a specific mode among the multimode laser light. The block member can be provided in the package after the laser element is mounted, so that the block member can be simply attached without complex steps.

[0016]

The diameter D1 of the block member can be defined by the following formula:

[formula 2]

$$D1 = L1 \times 2\tan(\theta n/2)$$

where L1 is a distance from the surface emitting semiconductor laser device to the block member, θn is a divergence angle of emitted light of the specific mode from an optical source of the surface emitting semiconductor laser device in a far-field image

of the multimode laser light.

[0017]

Preferably, the block member is equipped with an antireflection film that prevents the multimode laser light from being reflected by the block member. The block member may include an absorption member that absorbs the light of the specific mode. Preferably, the surface emitting semiconductor laser device has a mesa that emits the multiple laser light, and the block member has a circular shape. It is desirable that the block member blocks of light of a fundamental mode among the multimode laser light, and the divergence angle θn is a divergence angle of a diameter of the light of the fundamental mode from an optical source of the surface emitting semiconductor laser device.

[0018]

By using a surface emitting semiconductor laser of the present invention as a light source and using a multimode type optical fiber optically coupled with the light source for optical communications, it is possible to provide a less expensive optical communication system having an improved frequency response and realizing a higher speed.

[0019]

[MODE FOR CARRYING OUT THE INVENTION]

A description will now be given of embodiments of the present invention with reference to the accompanying drawings.

Fig. 1A is a cross-sectional view of a VCSEL according to a first embodiment of the present invention taken along a line X1-X1 shown in Fig. 1B that is a plan view of the VCSEL, and Fig. 1C shows a relation between the size of a block member and an emission aperture.

[0020]

A multimode surface emitting semiconductor device 100 has an n-type GaAs substrate 1 on which laminated are an n-type lower multilayer reflection film 2, an undoped active region 3, a current confinement layer 4 having a circumferential peripheral region surrounded by an oxidized region 4a and a conductive region of a circular shape arranged at the center, a p-type upper multilayer reflection film 5, a p-type contact layer 6, an interlayer insulation film 7, a p-type upper electrode 8, and a block member 9 provided in the emission aperture 11. An n-type backside electrode 10 is provided on the backside of the n-type GaAs substrate 1.

[0021]

A cylindrical mesa or post 101 is formed on the substrate 1 so that the post

101 ranges from the contact layer 6 to the active region 3. The bottom of the post 101 is an exposed portion of the lower multilayer reflection film 2. The interlayer insulation film 7 totally covers the bottom and side of the post 101, and partially covers the top of the post 101. On the top of the post 101, the upper electrode 8 for making an electrical contact with the contact layer 6 is disposed. Further, the upper electrode 8 defines the emission aperture 11, which is a circularly-shaped aperture. The upper electrode 8 extends from the top of the post 101 to the bottom thereof via the side, and is connected to an electrode pad (not shown).

[0022]

The circular block member 9 is placed on the emission aperture 11. The block member 9 and the emission aperture 11 are concentrically arranged, and the centers thereof coincide with the optical axis of the post 101. The block member 9 should have an ability of blocking light from the post 101, and may be made of a metal or another kind of material. Preferably, the block member 9 is made of the same material as the upper electrode 8. In this case, the block member 9 and the upper electrode 8 can be defined simultaneously. As will be described later, the block member 9 blocks light of a specific mode among the multimode laser beams emitted from the post 101. The current confinement layer 4 includes a conductive region formed by the AlAs layer and the oxide region 4a that surrounds the periphery of the conductive region. The oxide region 4a is formed by selectively oxidizing the AlAs layer from the side surface of the post 101. By controlling the oxidization distance from the side surface of the post 101, it is possible to obtain a desired aperture size suitable for the outer diameter of the post 101. In the present embodiment, in order to oscillate the multimode laser beams, the current confinement layer 4 is designed so that the conductive region has a diameter D2 of 8 microns, and the emission aperture 11 has a diameter D3 of 10 microns. The block member 9 is designed to have a diameter D1 of 3 microns.

[0023]

As has been described previously with reference to Fig. 7, the selective oxidization type multimode surface emitting semiconductor laser generates the fundamental mode within the angle θ_0 about the optical axis of the optical source, and generates a higher-order mode at an angle larger than the angle θ_0. The optical power of the higher-order mode is greater than that of the fundamental mode. The frequency response of the fundamental mode in the inner area P0 of the doughnut-like profile is greater than that in the outer area P1. In the present embodiment, since the block member 9 is provided in the emission aperture 11, the light of the fundamental

mode is blocked. The optical power of the fundamental mode is smaller than that of the light of the higher-order mode. Thus, even if the fundamental mode is cutoff, the total optical power will not be greatly reduced. By shutting out the light of the fundamental mode, the time difference in response between the modes can be reduced, so that the jitter contained in the laser beam can be reduced and the frequency response can be improved.

[0024]

Fig. 2 shows a laser profile of the laser beam in a far-field image with the block member 9 and an output profile thereof. The light of the fundamental mode among the multimode laser beams has an angle θ_0 in the far-field image at a distance L from the optical source. The block member 9 is designed to have a diameter D1 enough large to cover the angle θ_0, and may be 3 microns in the present embodiment. Thus, the light of the fundamental mode among the beams emitted from the post 101 is shut out by the block member 9, and the remaining beams are emitted via the emission aperture 11. The inner region P0 of the doughnut-like profile is totally covered by the block member 9, while only light of the first-order or higher-order mode located on the outer area P1 can be emitted.

[0025]

The use of the block member 9 brings about an improved eye pattern as shown in Fig. 8B. As compared to the conventional laser in the absence of any block member, according to the present embodiment, the eye pattern is converged and the jitter J1 is reduced.

[0026]

A description will now be given of a surface emitting semiconductor laser according to a second embodiment of the present invention with reference to Figs. 3A and 3B. Fig. 3A is a plan view of the surface emitting semiconductor laser mounted on a metal stem (a cap has been removed from the stem), and Fig. 3B is a cross-sectional view taken along line X2-X2 shown in Fig. 3A.

[0027]

A laser device 120 according to the second embodiment of the present invention does not employ the block member 9 in the emission aperture 11 of a surface emitting semiconductor laser 110, but includes a block member in a transmission window of a casing body on which the semiconductor laser is mounted.

[0028]

The surface emitting semiconductor laser device 110 includes a metal stem 20, and a metal cap 30 attached to the metal stem 20. The metal stem 20 is a thin plate of a circular shape, and has a ring-shaped flange 21 including a step on the

circumferential periphery of the metal step 20. The cap 30 has a single open side, and includes an inside hollow cylindrical space. The cap 30 has an end portion 31, which is formed on its circumferential periphery and horizontally protrudes from the side surface thereof. A circular transmission window (aperture) 32 is formed in the center of the cap 30. A circular glass member 33 is attached to the back surface of the cap 30 so as to match the shape of the back surface. Preferably, the peripheral surface of the glass member 33 is fused and fixed to the back surface of the cap 30. The glass member 33 closes the transmission window 32 formed in the cap 30. The transmission window 32 serves as a path window via which the laser beam emitted from the post of the surface emitting semiconductor laser 120. The end portion 31 of the cap 30 is fixed to the flange 21 by welding or the like. The cap 30 and the metal step 20 define an inside closed cavity, which is filled with nitrogen. A circular block member 34, which is concentrically arranged with the transmission window 32, is fixed to the glass member 33. The glass member 33 has a size enough large to block the light of the fundamental mode among the multimode laser light emitted from the semiconductor laser 120.

[0029]

The metal stem 20 has through holes 22 and 23 to which a pair of lead pins 40 and 41 is attached. The pair of lead pins 40 and 41 is provided with an insulating film 24 by which the lead pins 40 and 41 are electrically isolated from the metal stem 20. Ends of the lead pins 40 and 41 protrude from the surface of the metal stem 20. The protruding portions of the lead pins 40 and 41 are connected to bonding pads 60 and 61 by bonding wires 50 and 51.

[0030]

A mounter 70 is attached to the center of the metal stem 20. The surface emitting semiconductor laser 120 is fixed to the mounter 70. The semiconductor laser 120 is the same as the semiconductor laser 100 shown in Figs. 1A through 1C except that the laser 120 does not have the block member 9. The mounter 70 may be made of, for example, a semiconductor material such as GaAs or ceramics such as AlO (alumina) and AlN (aluminum nitride). The surface of the semiconductor or ceramic material is plated with a metal such as Au. Alternatively, Au may be deposited on the surface. The n-side electrode 10 of the semiconductor laser 120 is connected to the metal surface of the mounter 70. Further, the electrode pad 61 is provided on the metal surface of the mounter 70. Furthermore, the semiconductor laser 120 includes the post 101 on the semiconductor substrate and includes the electrode pad 60 that is located close to the post 101 and is electrically connected to the p-side electrode 8. The lead pin 40 is electrically connected to the p-side electrode 8 via the bonding wire

50 and the electrode pad 60. The lead pin 41 is electrically connected to the n-side electrode 10 via the bonding wire 51 and the electrode pad 61.

[0031]

The center of the block member 34 is located on the optical axis of the post 101. As is shown in Fig. 2, the diameter D1 of the block member 34 can be defined as follows:

[0032]

[Formula 3]

$D1 = L1 \times 2\tan(\theta_0/2)$

where L1 is the distance from the post 101 serving as the optical source to the block member 34. In this case, the parameter θ_0 is the divergence angle of the diameter of the beam of the fundamental mode from the optical source (post) in the far-field image of the multimode light emitted from the optical source. With this arrangement, the block member 34 blocks only the light of the fundamental mode among the multimode light emitted from the post 101.

[0033]

The block member 34 may be made of a material capable of shutting out light, such as a metal or insulator. Preferably, the surface of the block member 34 is coated with an antireflection film in order to prevent light reflected by the block member 34 from traveling within the cap 30. An adhesive layer may be provided in order to facilitate adhesion of the block member 34 to the glass member 33. The block member 34 may be an absorption member capable of light having a specific wavelength. In this case, the wavelength to be absorbed is the wavelength of emission by the semiconductor laser 120.

[0034]

According to the second embodiment, after the surface emitting semiconductor laser is mounted, the block member 34 is merely fixed to the glass member 33 of the cap 30, so that the jitter-reduced multimode surface emitting semiconductor laser having improved frequency response can be fabricated without any complex process. The combination of the semiconductor laser thus obtained and the multimode optical fiber will achieve economical optical communication systems having a higher data transmission rate.

[0035]

A description will now be given, with reference to Figs. 4A to 4C, 5D to 5F and 6G to 6I, of a method of fabricating the surface emitting semiconductor laser according to the first embodiment of the present invention. Referring to Fig. 4A, the lower multilayer reflection film 2, the active region 3, the p-type AlAs layer 4, the

upper multilayer reflection film 5, and the AlAs contact layer 6 are laminated on the (100) surface of the semi-insulation GaAs substrate 1 in that order by MOCVD (Metal Organic Chemical Vapor Deposition). The lower multilayer reflection film 2 includes a laminate of pairs of an undoped $Al_{0.8}Ga_{0.2}As$ layer and an undoped $Al_{0.1}Ga_{0.9}As$ layer. The active region 3 is a laminate of a spacer layer formed by an undoped $Al_{0.4}Ga_{0.6}As$, a barrier layer formed by an undoped $Al_{0.2}Ga_{0.8}As$ layer, and a quantum well layer formed by an undoped GaAs layer. The upper multilayer reflection film 5 includes a laminate of pairs of p-type $Al_{0.8}Ga_{0.2}As$ layer and a p-type $Al_{0.1}Ga_{0.9}As$ layer.

[0036]

The lower multilayer reflection film 2 is composed of multiple pairs of an n-type $Al_{0.9}Ga_{0.1}As$ layer and an n-type $Al_{0.15}Ga_{0.85}As$ layer. Each layer is $\lambda/4n_r$ thick where λ is the oscillation wavelength and n_r is the refractive index of the medium. The paired layers having different composition ratios are alternately laminated to a thickness of 36.5 periods. The carrier concentration after the reflection film 2 doped with silicon as the n-type impurity is $3x10^{18}$ cm^{-3}.

[0037]

The active region 3 includes a laminate of an 8nm-thick quantum well active layer formed by an undoped GaAs layer and a 5nm-thick barrier layer formed by an undoped $Al_{0.2}Ga_{0.8}As$ layer, these layers being alternately laminated. The outer layer of the laminate is the barrier layer. The laminate is disposed in the middle of the spacer layer formed by an undoped $Al_{0.4}Ga_{0.6}As$ layer. The thickness of the spacer layer including the quantum well active layer and the barrier layer is designed to be an integer multiple of λ/n_r. The active region 3 thus formed emits 850nm light.

[0038]

The upper multilayer reflection film 5 is a laminate of pairs of a p-type $Al_{0.8}Ga_{0.2}As$ layer and a p-type $Al_{0.1}Ga_{0.9}As$ layer. Each layer is $\lambda/4n_r$ thick. The paired layers having different composition ratios are alternately laminated to a thickness of 22 periods, which include the underlying AlAs layer 4 and the uppermost GaAs layer 6. The AlAs layer 4 is not required to be AlAs throughout the thickness $\lambda/4n_r$ but may include anther semiconductor layer. If the AlAs layer is too thick, optical scattering loss may increase. In the present invention, the AlAs layer 4 is 30 nm thick;, and the rest is formed of $Al_{0.9}Ga_{0.1}As$. The carrier concentration after the layer 5 is doped with carbon as the p-type impurity is $4x10^{18}$ cm^{-3}.

[0039]

In order to reduce the series resistance of the device, an intermediate layer may be placed between the $Al_{0.8}Ga_{0.2}As$ layer and the $Al_{0.1}Ga_{0.9}As$ layer of the upper multilayer reflection film 5, wherein the intermediate layer has an Al composition ratio

between these layers.

[0040]

The uppermost layer of the upper multilayer reflection film 5 is the p-type GaAs layer that is 20 nm thick in order to improve the contact with the p-side electrode 8. The upper multilayer reflection film 5 has a carrier concentration of $1 \times 10^{19} cm^{-3}$ after it is doped with zinc as the p-type impurity.

[0041]

Next, as is shown in Fig. 4B, the substrate (wafer) is removed from the growth chamber, and a mask pattern 13 of SiO_2 is photolithographically formed on the substrate. With the SiO_2 pattern being used as a mask, the substrate is etched so that the cylindrical mesa or post 101 is formed thereon, as shown in Fig. 4C. Then, the upper multilayer reflection film 5, the AlAs layer 4 and the active region 3 are anisotropically etched by reactive ion etching (RIE).

[0042]

After the post 101 is formed, the side surface of the AlAs layer 4 is exposed. The substrate (wafer) is exposed to a vapor atmosphere at 350 °C with nitrogen being used as carrier gas (flow rate: 2 liters per minute) for 30 minutes. The AlAs layer 4, which forms a part of the upper multilayer reflection film 5, has an oxidization rate that is very higher than that of the $Al_{0.8}Ga_{0.2}As$ layer or $Al_{0.1}Ga_{0.9}As$ layer which layers form a part of the AlAs layer 4. As shown in Fig. 5D, oxidization starts from the side surface of the AlAs layer 4 just above the active region 3 included in the post 101. This oxidization eventually makes the oxide region 4a that reflects the shape of the post 101. The oxide region 4a has a reduced conductivity and serves as a current confining portion. Further, the oxide region 4a has an optical reflectance (~1.6) that is approximately half the reflectance of the layers, and thus serves as a light confining region. The rest of the AlAs layer 4 that has not been oxidized serves as a conductive region and functions as a current injection part. The aperture of the conductive region has a diameter as large as 10 microns for emission of multimode light.

[0043]

Thereafter, as shown in Fig. 5E, the mask 13 is removed and the exposed side surface of the post 101 is coated with the insulation film 7 that also covers the substrate. Then, as shown in Fig. 5F, a contact hole 7a is formed in the top of the post, so that the interlayer insulation film 7 can be defined.

[0044]

Then, as shown in Fig. 6G, an electrode layer is provided on the entire substrate (wafer) including the post 101, and is then patterned, as shown in Fig. 6H. The p-side electrode 8 defines the emission aperture 11 on the top of the post 101, and

simultaneously, the block member 9 is formed. After that, as shown in Fig. 6I, the n–side electrode 10 is formed on the backside of the substrate 1. In the above-mentioned manner, the surface emitting semiconductor laser shown in Figs. 1A through 1C can be produced. The surface emitting semiconductor laser 110 according to the second embodiment of the present invention, the p-side electrode is patterned so that the block member 9 does not remain.

[0045]

The present invention is not limited to the specifically disclosed embodiments, and variations and modifications may be made without departing from the scope of the present invention.

[0046]

In the first and second embodiments of the invention, the light of the fundamental mode is blocked. Alternatively, light of another specific mode may be blocked to reduce the jitter contained in the light signal. Preferably, modes that have a relatively low frequency response are selected. The shape of the block member may be selected in accordance with the mode to be cutoff. The material of the block member may be metal or insulator. It is essential to select a material that can block light of the selected mode. In this regard, the block member may be made of a material that can absorb light of the selected wavelength.

[0047]

[EFFECT OF THE INVENTION]

According to the present invention, light of the specific mode is blocked or cutoff by means of a member provided in the emission aperture of the surface emitting semiconductor laser capable of emitting multimode laser light. It is therefore possible to reduce jitter contained in the light signal and improve the frequency response and to transmit data at a higher bit rate.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1] Fig. 1 shows a structure of a surface emitting semiconductor laser in accordance with a first embodiment of the present invention, in which (a) is a cross-sectional view of a surface emitting semiconductor laser according to a first embodiment of the present invention taken along a line X1-X1 shown in (b). (b) is a plan view of the surface emitting semiconductor laser according to the first embodiment of the present invention; and (c) shows a relation between a block member and an emission aperture in the first embodiment of the present invention.

[Fig. 2] Fig. 2 shows a light output of a far-field image by the surface emitting semiconductor laser shown in Fig. 1.

[Fig. 3] Fig. 3 shows a structure of a surface emitting semiconductor laser in

accordance with a second embodiment of the present invention, in which (a) is a plan view of a surface emitting semiconductor laser device according to a second embodiment of the present invention, and (b) is a cross-sectional view taken along a line X2-X2 shown in (a).

[Fig. 4] Fig. 4 shows a part of a method of fabricating the surface emitting semiconductor laser according to the first embodiment of the present invention.

[Fig. 5] Fig. 5 shows another part of the method of fabricating the surface emitting semiconductor laser according to the first embodiment of the present invention.

[Fig. 6] Fig. 6 shows yet another part of the method of fabricating the surface emitting semiconductor laser according to the first embodiment of the present invention.

[Fig. 7] Fig. 7 shows a light output of a far-field image by the surface emitting semiconductor laser shown in Fig. 1.

[Fig. 8] Fig. 8 shows eye patterns of laser beams; and

[EXPLANATION OF LETTERS OR NUMERALS]

1 GaAs substrate
2 lower reflection
3 active region
4 current confinement
4a oxide region
5 upper reflection
6 contact layer
7 interlayer insulation
8 upper electrode
9 block
10 n-side electrode
11 emission aperture
20 metal stem
30 cap
32 transmission window
33 glass member
34 block member
40,41 lead pins
50,51 bonding wires
60,61 bonding pads
70 mounter

100,110 surface emitting semiconductor laser device
111 post

[DOCUMENT NAME] ABSTRACT

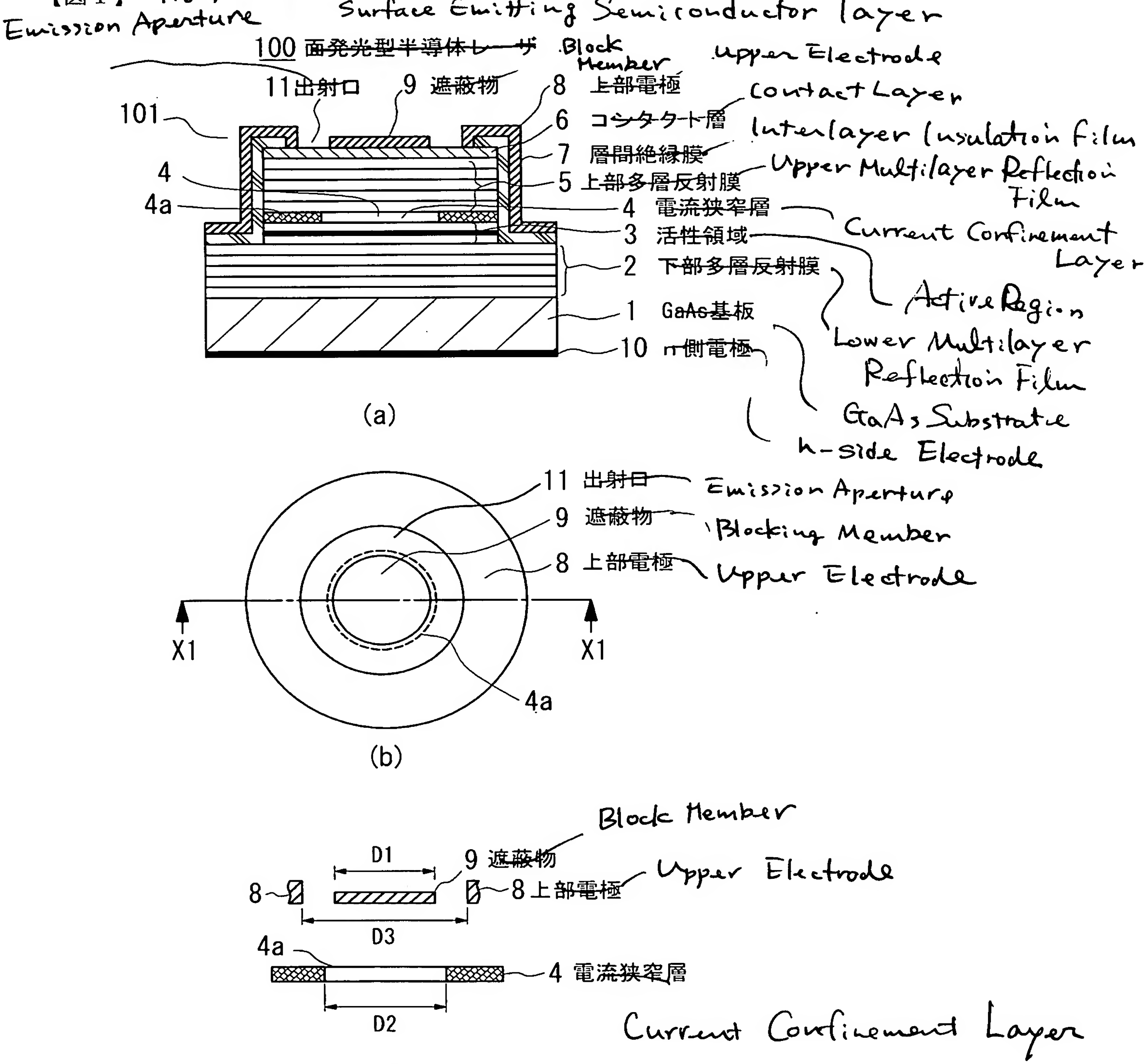
[PROBLEMS TO BE SOLVED] To provide a multimode type surface emitting semiconductor laser capable of restraining jitter components of laser light of multimode.

[MEANS FOR SOLVING PROBLEMS] A surface emitting semiconductor laser 100 capable of emitting laser light of multimode is characterized in that a block member 9 of blocking a specific mode out of the multimode is provided in an emission aperture 11 of laser light. The surface emitting semiconductor laser 100 includes, on a substrate 1, a lower reflection mirror 2, an upper reflection mirror 5 and an active region 3 and a current confinement layer 4 provided between the mirrors, the emission aperture 11 being formed above the upper reflection mirror 5. A post (mesa) 101 of a column shape is formed so as to extend from the upper reflection mirror 5 and reach the current confinement layer 4, and the emission aperture 11 and the block member 9 have circular shapes.

[FIGURE SELECTED] Figure 1

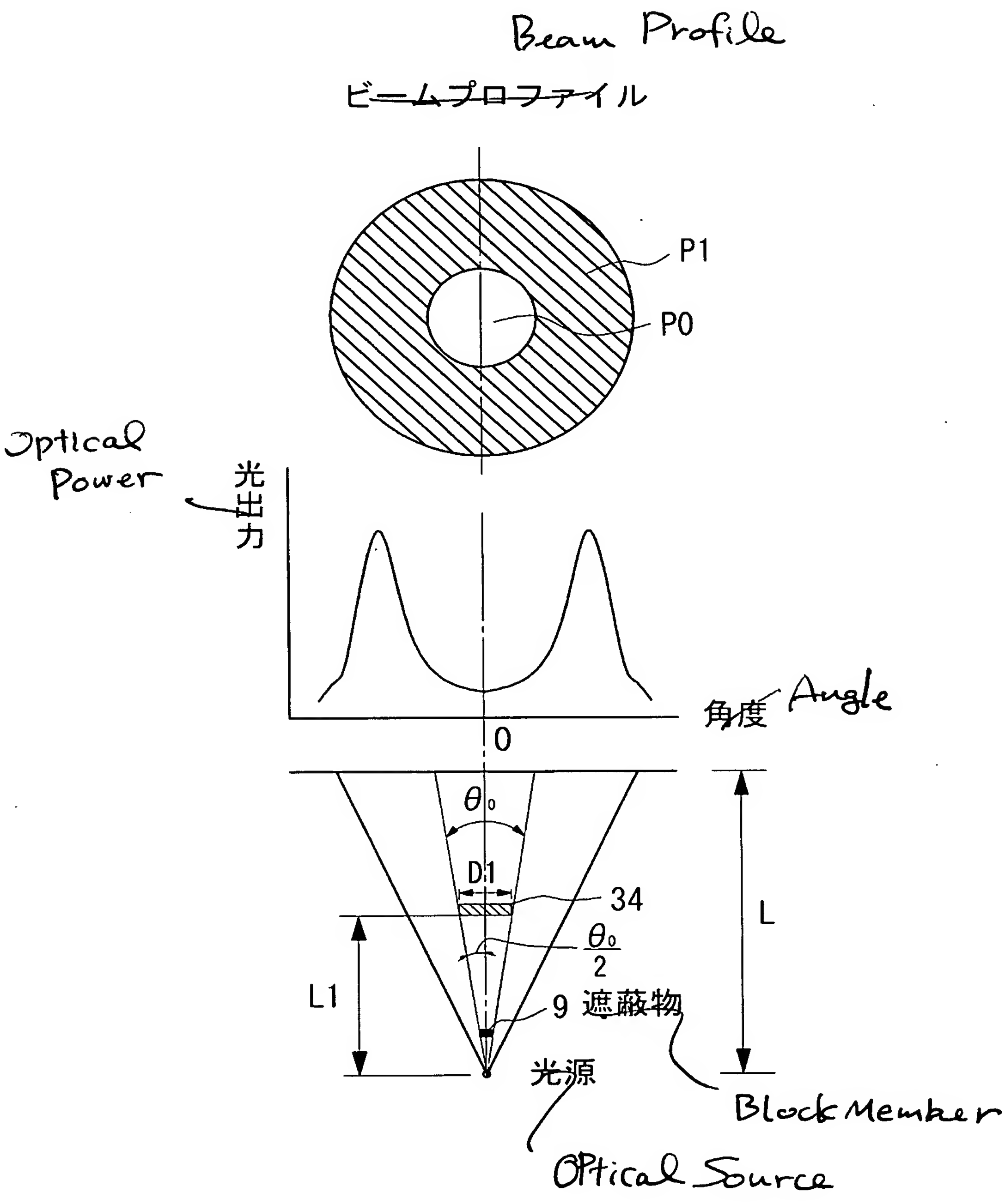
【書類名】　図面
Document　Drawings

【図１】 Fig.1

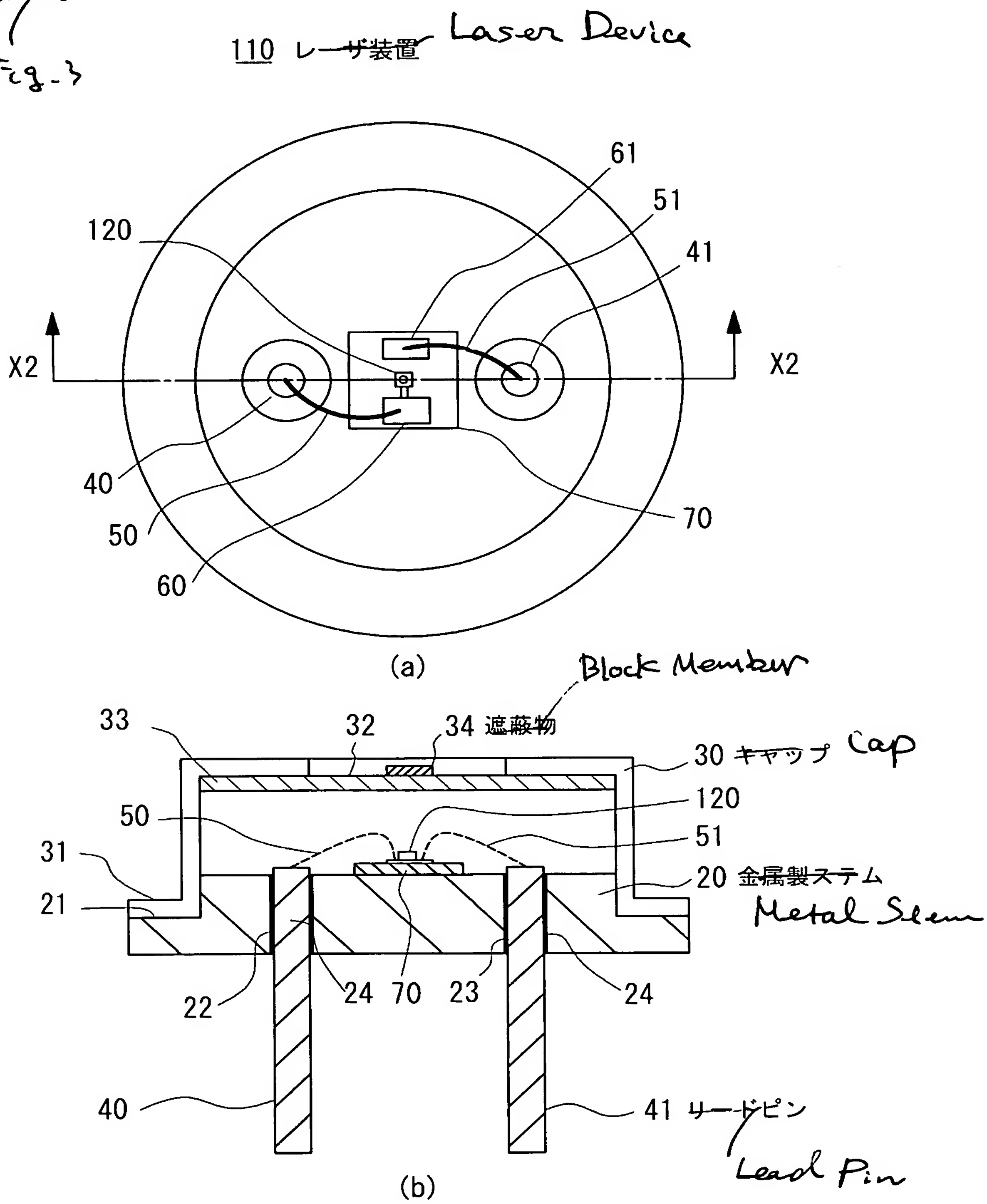


【~~図2~~】

Fig. 2

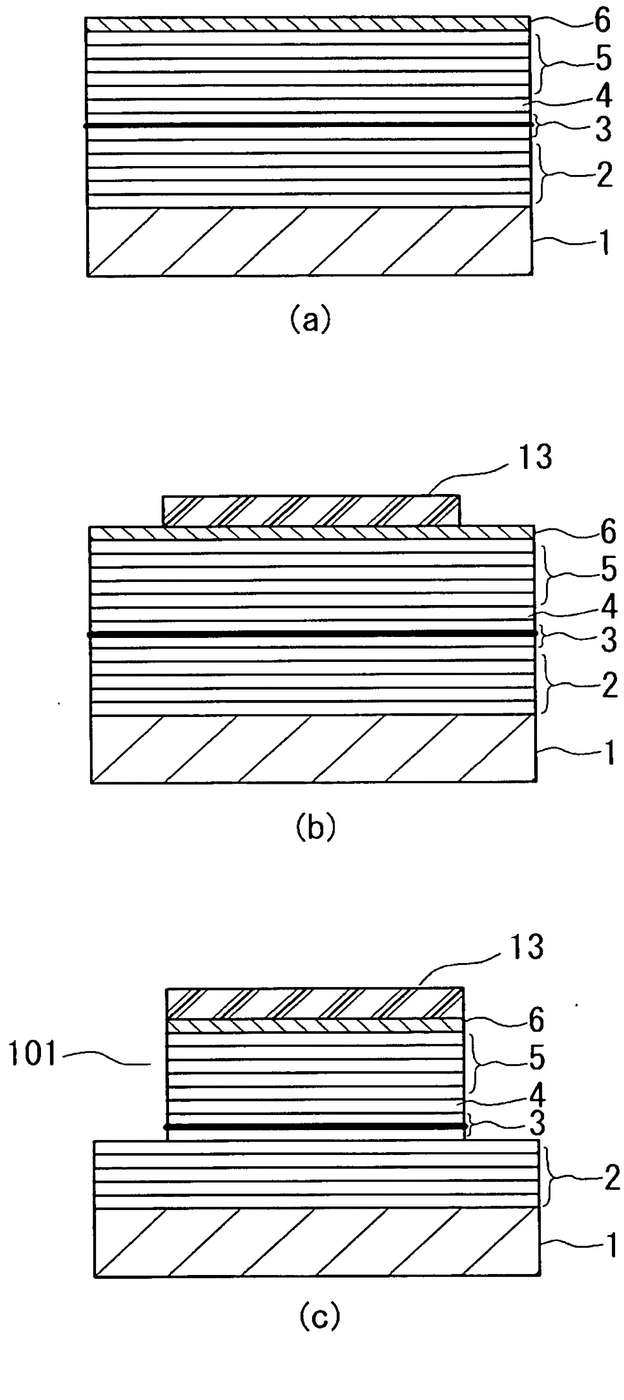

Beam Profile
~~ビームプロファ~~イル
P1
P0
Optical Power
光出力
角度
Angle
0
θ_0
D1
34
L
$\frac{\theta_0}{2}$
L1
9 遮蔽物
Block Member
光源
Optical Source

【図３】
Fig. 3


110 ~~レーザ装置~~ Laser Device
61
51
41
120
X2
X2
40
50
60
70
(a)
Block Member
33
32
34 ~~遮蔽物~~
30 ~~キャップ~~ Cap
120
50
51
31
20 ~~金属製ステム~~ Metal Stem
21
22
24
70
23
24
40
41 ~~リードピン~~ Lead Pin
(b)

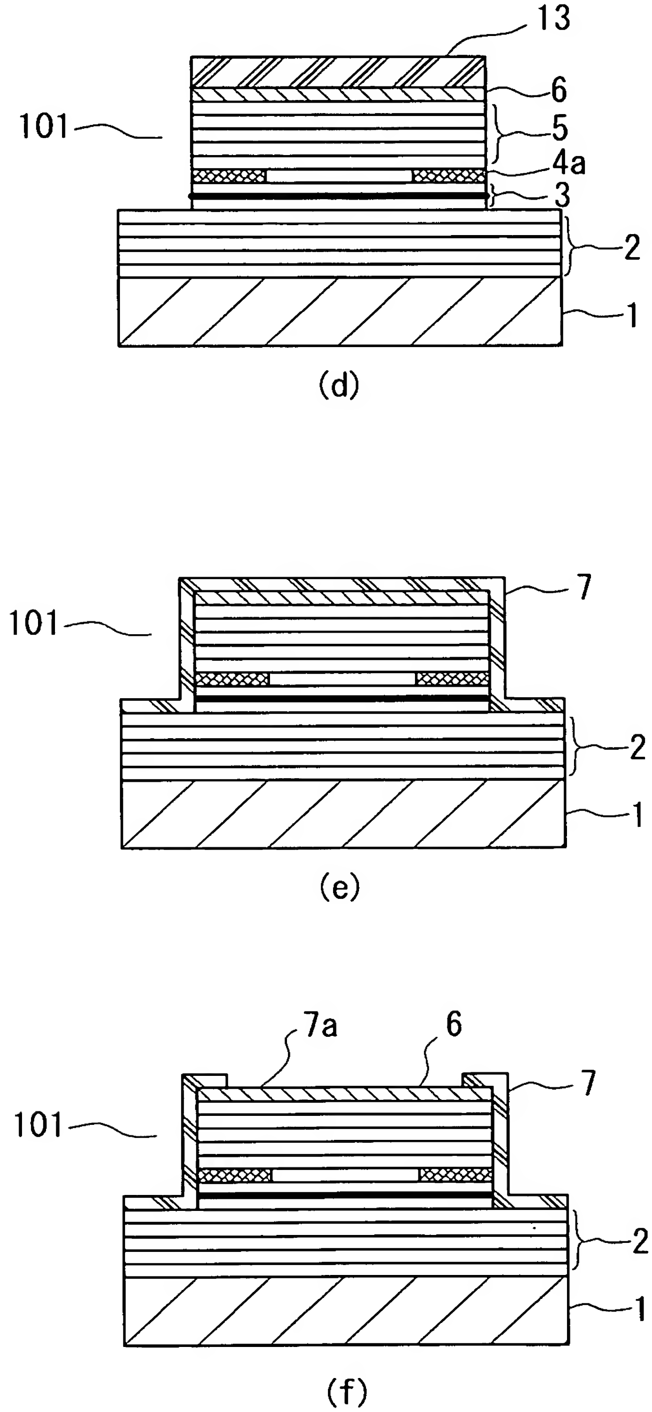
【図4】

Fig.4



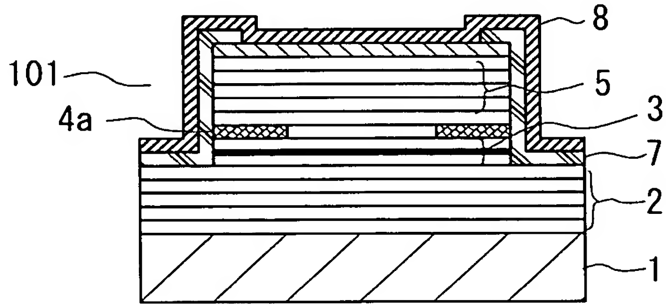
【図5】

Fig.5



【図6】

Fig. 6



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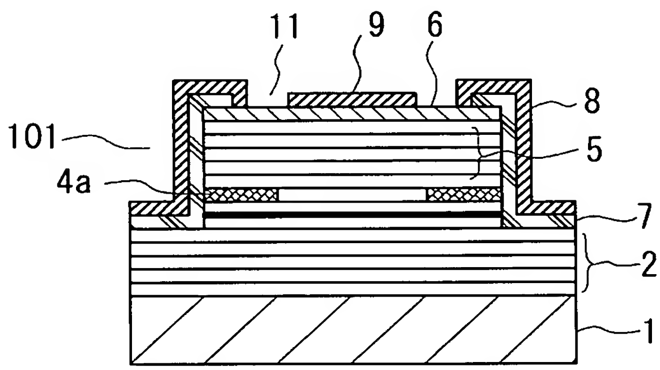

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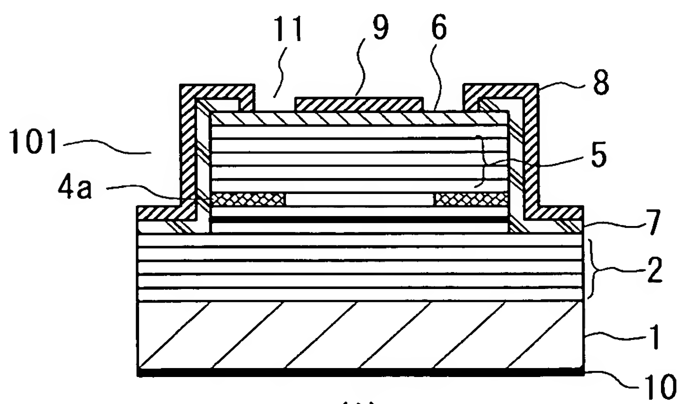
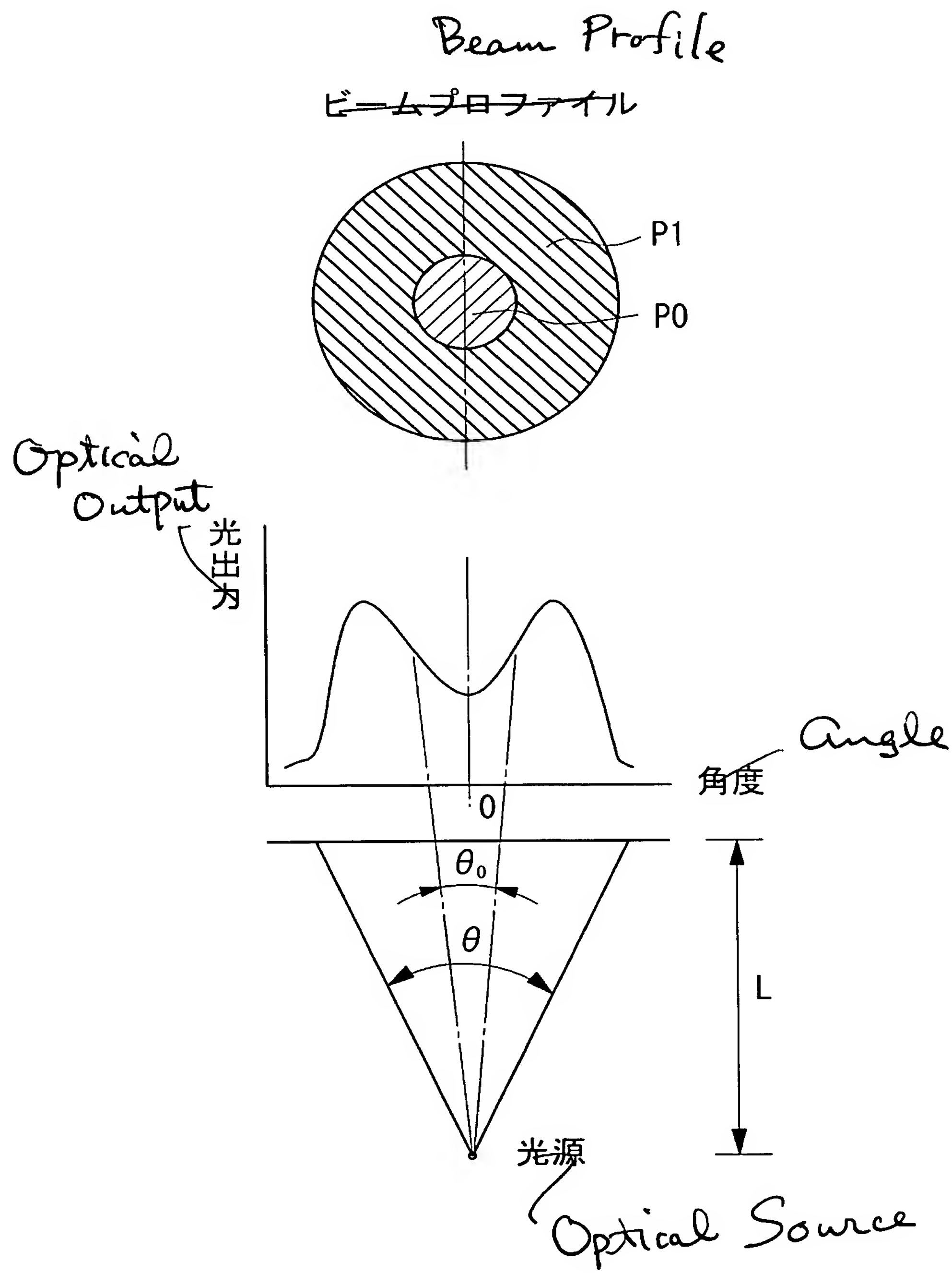


(i)

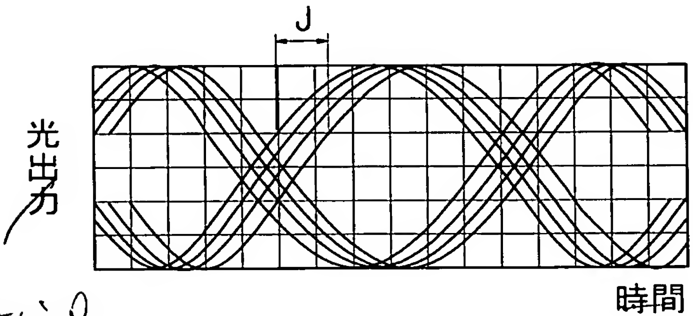
【図7】

Fig. 7

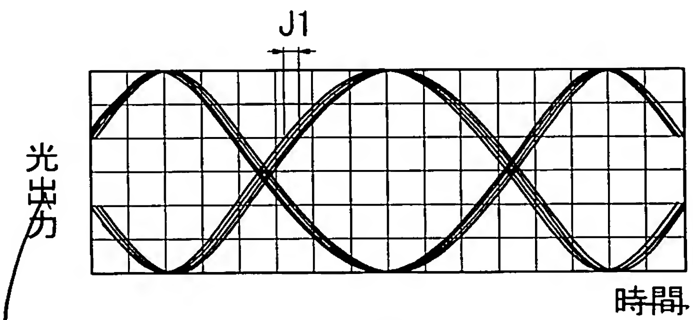

Beam Profile
~~ビームプロファイル~~
P1
P0
Optical Output
光出力
角度
Angle
0
θ_0
θ
L
光源
Optical Source

【図8】

Fig. 8



(a)



(b)